THE GENETICS OF HUMAN NATURE

BY JOSHUA LEDERBERG

MY PRIMARY intentions in this article will be: (1) to expose a philosophical viewpoint about human nature which is reinforced by elementary facts about the nature and place of man in the universe; (2) to discuss the idea of "natural" in the context of evolutionary adaptation; (3) to offer some impressions of the current status of experimental and human biology and of its possible relevance to contemporary social controversy; and (4) to discuss some areas of convergence of social and biological research. In undertaking this task I had in mind not only the fulfillment of a communicative responsibility to others but the opportunity to educate myself about the perceptions of biological research that might be entertained by students of society.[1]

Man[2] *in the Cosmos*

From the cosmic perspective[3] the human experience is a transient thermodynamic fluctuation on a minor planet. We do not yet

[1] I pretend neither total ignorance nor critical coverage of the literature. Indeed, I did not have time even to read the parallel contributions to this issue. My method is introspective reflection based on general culture in the field. The self-perceived audience also plays a vital role even for introspection. In educational and other interpersonal processes the state of memory and of consciousness of relationships depends on the perception of who may be listening. (To say "listening" for "reading" already betrays a quest for intimacy.) The discipline of adopting another's frame of reference so as to insure communication goes beyond drives discussed under the heading of "social facilitation"; cf. N. B. Cottrell in Charles G. McClintock, ed., *Experimental Social Psychology* (New York: Holt, Rinehart and Winston, 1972). For a critique of other aspects of dissociative learning, see M. E. Jarvik in *Annual Review of Psychology,* XXIII (1973), 457.

[2] The arrogation of the term for one sex to mean also the entire species is noted here as an occasion to abjure any unintended implications of persevering with the cliché. In this article, "man" will mean the species and "male" will be used for the hemizygous sex.

[3] An excellent way to call the cosmic muse is to peruse a charming picture book, Kees Boeke, *Cosmic View: The Universe in 40 Jumps* (New York: John Day, 1957).

know how to verify empirically the theoretical speculation that the universe abounds with intelligent beings like ourselves.[4] Having just begun the vehicular exploration of space, we have still to ascertain whether primitive forms of life are to be found even within our solar system. We have more or less abandoned any prospect of finding intelligent beings on Mars or Jupiter. Nevertheless, were they flourishing on other stellar systems as close as ten light-years away, we would probably still be ignorant of them. And the scale of the visible universe is measured in billions of light-years.

Man is also a fluctuation in the dimension of time. Of life's hour on earth, our species spans only the last second; the term of history is only the last blink.

The biological scientist is oriented to look at life as mechanism. Nay-sayers would have discouraged biochemistry in advance by insisting on unanalyzable vital principles to account for fermentation, for the reproduction of the gene, and still today for consciousness. The pursuit of mechanical explanations of vital phenomena may still be frustrated by some hitherto undemonstrated principle whereby these phenomena deviate from the laws of chemistry and physics. However, until now, the mechanistic hypothesis has yielded promethean advances in scientific knowledge, in medicine, and in man's dominion over the earth.[5]

Nevertheless, to speak of man as a *mere* machine[6] is a value judgment that has no place in authentic scientific discourse.[7] In fact, efforts to apply mechanistic biology in the sphere of human

[4] I. S. Shklovskii and Carl Sagan, *Intelligent Life in the Universe* (San Francisco: Holden-Day, 1966).

[5] A Pyrrhic victory?

[6] This value-reductionist phrase is, with few exceptions, a straw man designed as a target for detractors of science; cf. Arthur Koestler and J. R. Smythies, eds., *Beyond Reductionism: New Perspectives in the Life Sciences* (London: Hutchinson, 1969).

[7] Jacques Monod, *Chance and Necessity* (New York: Alfred A. Knopf, 1971), points out that a unique feature of scientific discourse is the demand that value statements be made explicit and separate from statements about nature. More difficult is the dissection of value-implications in the choice of which statements to investigate and assert.

values have been either futile or disastrous — which is to say that they are on a par with the success of other monolithic belief-systems in the ordering of human affairs. The grounds of this tragic dilemma in human nature need further harrowing.

The Cosmic-scientific perspective on man, which depicts him as a material infinitesimal, is undeniably orthogonal, rather than antithetical, to the humanistic perspective that accompanies our self-appreciation of human worth and dignity. The ethical standards by which scientists live, in their private and public lives, are not notably different from those of their companions of a given level of income and education. Most scientists have implicitly adopted a doctrine of scientific authenticity that concedes the autonomy of human ethical values (*pace* Marx).[8] We must admit that the dilemma is not really resolved, merely submerged. By the act of commitment of his life energy, the scientist is expressing a conviction about the relative worth and durability of dispassionate knowledge as compared to subjective feeling and interpersonal power.[9]

The Concept of "Natural"

To the biologist the concept of "natural," as expressed in phrases like "the wisdom of nature," is closely connected with evolutionary adaptation. Thus, he can translate the advocacy of "natural foods" into a biochemical argument. Only the most careful scrutiny can determine whether the metabolic machinery that we have evolved over eons to cope with natural produce will be compatible with artificial substitutes and additives.

[8] J. D. Bernal, in *Science and History*, 3rd ed. (New York: Hawthorn Books, 1965), traces this dualism to Descartes' timid expediency in the face of ecclesiastical power after Bruno was burned.

[9] The role of the physician is also riven by this conflict. His skill at *cure* has advanced enormously through the application of mechanistic biology; many patients — if not suffering from acute, life-threatening disease — miss the *care* that may now be more appropriately delegated to another profession. We see the same potential conflict in higher education, reaching its most inflammatory focus on the failure to qualify for tenure on the part of professors who may be better performers or counselors than scholars.

On this basis, synthetics may be judged entirely by their chemical composition. The problem is that subtle differences (e.g., free amino acids versus intact natural proteins, or the presence of trace minerals) may prove to be more important than is evident at first. Superficially attractive innovations may then cost a good deal in terms of subtle hazards or compensatory vigilance.

The yearned-for return to an original state of nature has its own complications. The operational process of evolutionary fitness is maximum competitive reproductivity, which may be irrelevant — or at worst contrary — to the enrichment of the individual life. Evolutionary adaptation has not always been successful from a human standpoint: witness the vulnerability of our coronary and cerebral blood vessels, and such unnatural and unhealthy vices as addiction to tobacco or opium. Other species have evolved in natural competition with our own: witness the multitude of plant and animal poisons. The natural evolutionary process has placed no special premium on *human* life. It might be perfectly "natural" for a new virus to emerge that would eliminate our own species as others have been eliminated.

The details of evolutionary change are often in paradoxical conflict with naïve ideas of biological harmony. Many serious genetic diseases — like sickle-cell anemia among Africans, and probably amaurotic infantile idiocy among Ashkenazi Jews and cystic fibrosis in Northern Europe — are by-products of evolutionary advance. In these examples of *polymorphism* a mutant gene has become established in the human gene pool by the circumstantially superior fitness of the heterozygote. (Sickle-cell carriers are relatively immune to malaria.) Were it not for the defect in the homozygotes, these genes would surely have spread unchecked throughout the entire population. As it is, that spread is stemmed at the point of balance where the final net advantage to the fitness of the species is marginal.[10]

[10] In human terms these kinds of adverse genes which allow the birth of handicapped children are far more tragic than statistical impairments of fertility which may be just as important from the standpoint of evolutionary fitness. Fortunately,

At this point in history, tragic polymorphic disease is an atavism which would spontaneously breed itself out of the race, but at a terrible price: the premature death of the afflicted children. Doctors are working hard to mitigate this natural imperative with humane arts, like therapy.

These polymorphisms provide a biological basis for the encouragement of outbreeding to minimize the relative incidence of homozygotes. The problematical role of instinctive prelearning (evolved behavioral patterns of sibling indifference) in reinforcing the incest tabu illustrates the poorly understood reticulation of gene and culture that is the typical challenge of human biology today. Nevertheless, the analysis of polymorphisms is a considerable advance over the folklore of "bad seed" that permeates lay conceptions of genetics. For example, even some physicians are unaware that an inbred parent who does not himself manifest the disease is at no disadvantage in further transmission of genetic defects.[11]

The gravest complication, however, is the one which is embodied in the legend of the fall of man in Genesis. This is a mythical expression of the preeminence of culture over nature, of the emergence of the superorganic beyond the organic, of the concept that man is a man-made species. The theme hardly needs elaboration here.

Nevertheless, the last century (i.e., since the Darwinian turning point) has seen many ill-fated efforts to justify social systems, be they utopias or the status quo, on biological grounds. The great debate between T. H. Huxley and Herbert Spencer epitomizes a recurrent conflict. The biologist had his troubles with the religious establishment over the biology of evolution. But he argued against the philosopher that, far from being the ethical foundation of human life, the evolutionary principle needs constant correc-

---

the most damaging mutations result in fetal wastage, early spontaneous abortion, rather than damaged but live-born children.

[11] In fact, by having exposed their genes to natural selection, such parents are at smaller risk of transmitting masked defects than their outbred cousin.

tion and intervention by human intelligence if ethical purposes are to be achieved.[12]

An underlying motif of evolutionary ethical argument is the superordinate value of the species or the group in contrast to the individual. But it is one thing to advocate altruism; ethically quite another to enforce it through political institutions. Even the strongest advocates of collective altruism in the sphere of economic justice demand the utmost scruples in the recruitment of human subjects for medical experimentation – the enormous aggregate interest of the group in new medical discovery weighs very little against the personal rights of the individual.[13] Altruism as an ethical principle has a scientific foundation only insofar as human evolution has depended on it. But this has also depended on competitive behavior that we might prefer to outgrow. It is then an autonomous ethic, not an inference from biology. Knowledge of human evolution and human biology can of course help in formulating efficacious means to implement autonomous ideals.

The worst inhumanities have also relied upon egregiously bad science: Hitler's extermination of the Jews of Europe was rationalized by a theory of human genetics that was universally rejected (if perhaps not sufficiently overtly condemned) by contemporary genetic science – and yet it will for a long time make it very difficult to discuss any eugenic policies whatsoever, no matter how different they may be either in political motivation or in scientific integrity.[14]

[12] A pervasive fallacy in evolutionary ethics is the confusion of "is" with "ought," which can even lead to correct or incorrect conclusions for irrelevant reasons. A preeminent ethologist has concluded "that on biological as well as traditional grounds it is to his sovereign state that the individual's first loyalty should continue to be given" (V. C. Wynne-Edwards, "Ecology and the Evolution of Social Ethics," in J. W. S. Pringle, ed., *Biology and the Human Sciences* [New York: Oxford University Press, 1972], p. 49). His principal argument is the observation that individuals exhibit feeble loyalties to supranational organizations.

[13] Paul A. Freund, ed., *Experimentation with Human Subjects* (New York: George Braziller, 1970).

[14] Kenneth M. Ludmerer, *Genetics and American Society* (Baltimore: Johns Hopkins University Press, 1972).

The eugenic movement in the United States had stronger but still imperfect scientific foundations, and was less aggressive in its policy means; nevertheless, it also left another irremediable stain. We now know that laws that permit the sterilization of the mentally deficient on genetic grounds cannot be justified, for there has rarely been evidence that the defect was heritable in the specific cases — even where Justice Holmes believed that "three generations of idiots is enough." Tragically, this error and other deficiencies in procedural safeguards have so inflamed the issue that it is difficult to discuss the merits of sterilization on personal as opposed to genetic imperatives.

Human Biology — A New Discipline?

For over a century scientific biology has made important contributions to human welfare, principally by its applications in medicine and agriculture. Today many new areas of social policy are making unanswered demands for scientific insight — fields like the resolution of conflicts over environmental values and hazards; the design of educational and manpower programs; the amelioration of public health through more refined preventive as well as therapeutic measures; the assessments of technological advances in many fields, some primarily connected, others marginal to biology. Conversely, many programs depending on medicine and the natural sciences have faltered when crucial behavioral and social factors were overlooked. Today, there are great expectations for a potential harvest from the no-man's-land between the research disciplines of biology and the social sciences.

The newly converted zealot may be both effective and dangerous in proportion to his enthusiasm. Many aspects of human biology are simply too poorly developed to justify any grand claims for early performance, notwithstanding the legitimacy of its aspirations. The biological components of human studies need many repairs; even more urgent may be a coherent integration of the social sciences among themselves. The purpose of achieving better

connections with biology for a more unified human science may accelerate the painstaking evolution of traditional disciplines.

Several routes to convergence may be cited: the reunification of psychobiology and biochemistry with psychiatry, in large part through the impact of new drugs effective in schizophrenia; efforts to promote a new research discipline of behavioral genetics;[15] an undergraduate curriculum of "human biology, and an honor school of human sciences at Stanford and at Oxford respectively."[16] With the task of developing an interdisciplinary understanding of man, these educational ventures may be the seat of a new "humanities" – but to do this they will have to pay still more attention to history, philosophy, and literature as well as to the sciences.

The two cultures are not about to be unified by a stroke of the pen, nor even by the best of good will among a group of cooperating teachers. Precisely because of the primitive level of its development, human science requires an inordinate amount of fuss and detail in order to do justice to its parts. Few teachers have the integrative genius needed to wring out the redundancies and to explore well defined issues from many complementary points of view. The very success of some established disciplines, like economics, puts off the prospect of major revision that might accommodate the viewpoints of the other social sciences, much less those of the biologist.[17]

The institutional problems of renovation of the historic disciplines are also well known, and they are by no means artificial ones. Without an authentic fellowship of peers, how is the innovator to be judged? How to separate the charlatan from the genius? Nor can a new science depend only on the labors of the remarkable intellects who can master two or more disciplines independently; it will have to allow for the aspirations of merely brilliant workers if much actual work is to be accomplished!

[15] For example, see Jerry Hirsch, ed., *Behavior-Genetic Analysis* (New York: McGraw-Hill Book Company, 1967).

[16] Pringle, *Biology and the Human Sciences.*

[17] But see Weisskopf in this issue.

Despite these difficulties, many people agree that the time is long past when students can be encouraged to pursue developmental psychology without an understanding of the biological substratum, any more than we can now encourage physicians to disparage the emotional sources of physical disease. The cosmic and the social views of man need to be brought into a creative synthesis to replace a wasteful conflict.

The term "human biology" then entails an inevitable ambiguity, for it must encompass both the more narrowly biological studies of man as an organism and the relationship of his biology with that social experience which is so uniquely human.

Human biology *sensu strictu* is itself retarded in many of its branches, perhaps by being overshadowed by medical scholarship, which has its own particular goals and concerns. Besides the actual ethical and logistic problems of experimental studies on human beings, there may be a temperamental barrier further discouraging those with a bent for incisive experimentation from entering a thicket of political and emotional hazards. The very notoriety that attends studies on the human brain, testes, and ovaries, which is a reflection of their social importance, may also deter some reputable investigators from focusing on such material. So now we know too little to deal effectively with many pressing problems. Reproductive biology, long neglected, has become a matter of human survival in facing the population crisis. We are still ignorant of many elementary aspects of the development of the human brain — but are ready to follow any of a variety of educational creeds which may profoundly alter the success and happiness of our children.

In any event, the situation today is that our knowledge of human biology[18] has many intermittent intersections with social research and social policy. These require the close attention of social scientists not only for their own edification but for the proper direction of the biological studies as well.

[18] We are fortunate to have a recent comprehensive monograph by J. C. Young, *An Introduction to the Study of Man* (Oxford: The Clarendon Press, 1971).

The principal perspectives of human biology are the evolutionary, the developmental, and the ecological. The evolutionary perspective shows us the biological continuity between man and his animal relatives, and may give some insight into the basis and bounds of his behavior. To look at man only as the product of organic evolution, without an understanding of the complexities of his individual development and of the social factors that play upon his individuation, is bad biology certain to lead to bad policy. To disregard his evolutionary heritage is to overlook some of the most fruitful sources of understanding of his behavior, especially in the light of experimental work on other animals which can be cautiously extrapolated to man. Almost all we know of the impact of hormones on behavior comes from animal studies with occasional glimpses from natural experiments — disease syndromes — skillfully analyzed when the doctor is also a student of nature. We have gone far beyond such simplistic notions as that testosterone is the hormone of male aggressiveness; yet there is little doubt that specific hormones, at crucial stages of the life cycle, play important roles in the setting of behavioral patterns. These fragments of insight into developmental behavioral biology should induce more humility than optimism. If we are still so perplexed about the relationship between hormones and behavior, how can we readily accept simple generalizations about the effects of genes! However, many workers are beginning to ask cogent questions of a kind that are now accessible to experimental analysis, and the next decade should see considerable advances on both the developmental and genetic sides.

The ecological perspective can hardly be overlooked. Man's survival on earth depends on his relationship with other plants and animals as well as with an environment whose capacity for self-purification, although large, is already taxed by the outflow of his cultural activity. The pace with which improvements in agriculture, including the perfection of food crops, can keep pace with the effective human demand, may determine the recent future of world history. Without a deep understanding of human

nutrition, crop developments have not always been tailored to our specific needs. The use of butterfat in milk as a convenient index of its quality clashes with contemporary ideas on preventing cardiovascular disease. This is a typical warning of the dangers of one-dimensional indexes for criterion functions in social policy.[19]

Although the theory of human evolution from apelike primate ancestors has received much observational support, and no serious scientific contradiction in the last hundred years, the details are still obscure.[20] The fossil evidence is understandably sparse, and every scarce scrap must be interpreted as far as the evidence will permit. Other sources of insight as to man's biological relationships have come from biochemical studies of the structures of related proteins, like those of the red blood cell hemoglobins in different species. These have amply confirmed the qualitative picture of relationship between man and primates and other mammals. None of these measures gives much direct insight into the unique element of human evolution, man's intelligence. In recent years, human biologists have been increasingly perceptive about the role of behavioral factors as inputs to, as well as consequences of, evolutionary change.[21] Studies of contemporary primates in the field become increasingly valuable as more species are examined. The diversity of responses should moderate overly enthusiastic extrapolations directly to man.

All available information, of course, concurs that contemporary man is a single species, capable of free interbreeding, and indeed with remarkably little genetic diversification even among major ethnic groups. The principal features that distinguish such groups are literally skin-deep — that is to say, those aspects of physical appearance that are most obvious to the unaided eye and can

[19] Otis D. Duncan, "Toward Social Reporting – Next Steps," in *Social Science Frontiers, 2* (New York: Russell Sage Foundation, 1969).

[20] For a remarkable overview, see John Pfeiffer, *The Emergence of Man* (New York: Harper & Row, 1970).

[21] D. Hamburg, in *Psychoanalytic Quarterly,* XLII (1973), 185–196.

therefore be directly related to processes of sexual selection.[22] The normative criteria of the group are therefore likely to have played as large a role in characteristic pigmentation or physiognomy of particular tribes as did physiologcal adaptation to the natural habitat. The search for more deep-seated biological differences among races has been remarkably unrewarding. We may conclude that, for significant periods of human evolution, the species has experienced a remarkable degree of gene-flow, by migration or by military capture.

Some of the problems of defining man as a species have been explored in Vercors's novel *And You Shall Know Them*. There is, in fact, no experimental information on the possibility of hybridization between man and other primates besides the evident absence of naturally occurring intermediate forms. The chromosome number in man is normally forty-six (twenty-three pairs), in contrast to the forty-eight exhibited by the higher apes. That this number was not correctly known until 1956,[23] when thousands of insect species had been correctly catalogued, is some evidence of resistance to human biology. However, many men are known with forty-five chromosomes[24] or as many as fifty, the latter resulting from replication of the X chromosomes, so this by itself cannot be taken as an ultimate biological criterion.

In fact, when the question "When does human life begin?" is put to the biologist in the framework of the abortion controversy, he is bound to reply: "At that time that accords with your own ethical requirements." He is bound to say that, from a genetic standpoint, human life is a continuum. His scientific analysis can

[22] This phrase is intended to encompass all the behavioral influences on reproductivity, of which voluntary mate-preference is only one. Group ostracism of a deviant child, if this results in reproductive discrimination, would be a potent form of sexual selection.

[23] J. H. Tjio and A. Levan, in *Hereditas*, XLII (1956), 1–6. In fact, other workers had been puzzled by seeing only forty-six chromosomes and had published figures accordingly – but blamed the apparent discrepancy from the textbooks' forty-eight on technical artifact! Other examples of "I'll see it when I believe it" abound in microscopy.

[24] These are single-X females, the Turner syndrome.

help to *apply* ethical criteria concerning the sources of human identity; he cannot *infer* them.

Studies of the human life cycle have, however, shown that about one-fourth of conceptions result in the loss of the fertilized egg or of the early fetus.[25] Many of these products of conception are severely damaged or chromosomally deficient. If the dignity of human life is to be attached to these organisms, and successful efforts made to rescue them, we would generate an awful burden of biological handicap. This knowledge by no means settles the ethical controversy about abortion. It cannot but complicate the consequences of insisting upon the unqualified right to life of every conceptus.

The sphere of the biological determination of temperament, intelligence, language-skills and other behavioral traits is perhaps the most important and the most confused arena of human biology. We do not have recourse to pure-bred lines, differing in well identified genes, that is available in mice. The general principle of genetic determination of behavioral traits is unassailable, but it is practically impossible at the present time to adduce nontrivial examples in man. This can well be illustrated by pointing out the utter confusion that now attends the biological versus the sociocultural determination of the differences between the two major genotypes of men, XX females and XY males.

The XYY chromosome condition — that is, males who have accidentally received an extra Y chromosome for a total of forty-seven—offers one of the most tangible leads for connecting genetic constitution with behavior in man.[26] Many XYY individuals have been encountered in institutions for the "criminally insane," a correlation that has aroused a certain morbid and generally inaccurate public interest. We still lack enough long-term longi-

[25] D. H. Carr, "The Genetic Basis of Abortion," *Annual Review of Genetics*, V (1971), 65–80; World Health Organization, *Spontaneous and Induced Abortion*, Technical Report Series, No. 461 (1970).

[26] E. B. Hook, "Behavioral Implications of the Human XYY Genotype," *Science*, CLXXIX (1973), 139–150; L. F. Jarvik et al., "Human Aggression and the Extra Y Chromosome—Fact or Fancy?", *American Psychologist* (in press).

tudinal studies to draw definite conclusions. The statistical evidence to date does suggest that XYY men, although for the most part indistinguishable from normal XY, are at greater risk of being subject to impulsive and sometimes criminal behavior. It is common experience that exactly the same can be said for the difference between XY and XX. However, the fact that XYY boys can be reliably distinguished from XY only by laboratory examination reduces the chance that these differences in behavior are confounded with the expectations of the other people in the milieu, a confusion that cannot be eliminated for boys versus girls. However, we have no clear evidence of the pathways that account for the occasional deviation of some XYY individuals from behavioral norms — which may well entail both developmental physiology and responses by the social group to other physical or behavioral features of the XYY boys. The study of such individuals, important for behavioral genetics, is clouded by the ethical constraints against labeling which may have self-fulfilling outcomes. Justice will not be achieved by ignoring these variations among humans; great wisdom is needed to work out the policies for further investigation and for the amelioration of risk to afflicted individuals.

At a time when the behavioral differences between XX, XY, XYY, etc. are still so problematical in their origin and development, it is hardly possible to find rigorous substantiation for ideas like the inevitable aggressiveness or territoriality of the human species. The complexities of defining aggressiveness, and the diversity of behavioral patterns found among other species, have been well addressed by Hinde.[27] In any event, modern warfare entails at least as much docile obedience and detachment from aggressive encounter as it does personal violence. One may therefore wonder whether the argument for the biological inevitability of war has not been fundamentally inverted.

More communication should be encouraged among social scientists who analyze violence as political process and ethologists and

[27] R. A. Hinde, "Aggression," in Pringle, *Biology and the Human Sciences,* p. 1.

psychiatrists who stress its irrational component.[28] The same can be said for the bureaucratic and psychodynamic interpretations of executive behavior in crisis.[29]

Some Frontiers of Policy and Human Biology

Throughout most of human history most of the gross world product of human labor was devoted to the creature needs of food and shelter. It was all but impossible to escape the iron law of efficiency in the allocation of human efforts and rewards. The surplus now generated by modern technology has set in motion the prevailing conflict of our own time between *efficiency* and *equality*. We observe a universally rising expectation of access to equal shares of justice, of health, of educational opportunity, of the enjoyment of common resources, of more and more of the technological surplus of worldly goods. It can even be remarked that man is the *envious* animal,[30] often demanding a fair share even if at the expense of an absolute gain.

The equality of man as a political commitment must confront the observed disparities among men as organisms and in their experience of the fortunes of history and of life. We have enough work to do to rectify historic injustices which have no defensible relationship to biological variability. In addition, we face an in-

[28] David N. Daniels et al., *Violence and the Struggle for Existence* (Boston: Little, Brown, 1970).

[29] Graham T. Allison, *Essence of Decision: Explaining the Cuban Missile Crisis* (Boston: Little, Brown, 1971).

[30] For example, one argument seriously proposed against further work on the development of an artificial heart has been that it would probably not be possible to make it uniformly available to all citizens for some period of time, and there would then be lacking the "social informed consent" for its availability to the few. Obviously, we need to find ways of solving these conflicts if we are to make major advances in any technical sphere. These must include ways of allocating and paying for life-saving capabilities. It is probably fair to say, however, that in contemporary society the rights of the few are more often neglected than overprotected. For more than one wants to know about *Homo invidius*, see Helmut Schoeck, *Envy: A Theory of Social Behavior* (New York: Harcourt, Brace & World, 1970). See also Raymond Aron, *Progress and Disillusion: The Dialectics of Modern Society* (New York: New American Library, 1969).

creasing variety of problems where the disparity of human natures poses great difficulties for the implementation of the egalitarian ideal. It would go too far beyond the scope of this article to discuss in detail the ethical and political ramifications of the social contract as it applies to the sharing of the hazards of life.

The problem can be epitomized by the extent to which we are willing to share social resources for the care of the physically handicapped.[31] In fact, even an infinite expenditure will not restore sight to the blind; moderate investments can enable the congenitally deaf to enter into the social stream. As we go further into the thicket of educational and social maladjustment, we encounter more entangled and problematical issues of the roles of biological and social causes. My own interest in applying information about such questions may be for the design of better public health measures.[32] Others translate a perceived dichotomy, biological versus environmental, into an allocation of responsibility, personal versus social; only when the handicap passes certain limits is the individual no longer responsible and may be a ward of the state.

The association of etiology and responsibility cannot be logically derived from biology, but many contemporary disputes about human variability are contaminated by it. Where the experimental evidence is also rather shaky, as in the genetic determination of intelligence or of social adjustment, the further confusion of frame of reference has exacerbated the conflict.

Genetic studies of the development of intelligence in man are hampered by the lack of any direct experimental methodology.[33]

[31] The disparity of death rates between males and females poses similar problems of equity in the design of insurance premium schedules. These are complicated by the free choice that the disadvantaged sex would enjoy in buying annuities or life insurance respectively and by the distinction between the interests of beneficiary and insured. Legal control of classification by race or social class may help enforce a redistribution to compensate for unjust differences in mortality. See "Sex Discrimination and Sex-based Mortality Tables," *Boston Law Review*, LIII (1973), 624–656.

[32] The dictum "Physician, know thyself!" may express intellectual curiosity as well as the drives for altruism and power.

[33] A. R. Jensen et al., *Environment, Heredity and Intelligence*, Harvard Educational Review Reprint Series, No. 2 (1969); cf. Hirsch, *Behavior-Genetic Analysis.*

Meaningful assays of intellectual potentiality are not available for the newborn. We would have no cognitive difficulty in designing inhuman environments which would deter the development of language and other manifestations of intelligence regardless of the infant's imputed potential. There is much experimental evidence in animals, and some corroboration from medical observation, for the existence of critical periods in the life cycle. Lacking appropriate environmental stimuli during such times, the young animal may, for example, be unable to organize the visual field in the brain. We should not be surprised to discover then that a host of imponderable factors play upon the full development of the child's cognitive functions.

Nevertheless, we can try to measure the relative contribution of genetic variation within a particular group to the variance of the final outcome. Such so-called measures of heritability can be estimated, albeit rather crudely, by studying the correlations between relatives of different degrees. Contrasts between monozygotic and dizygotic twins are especially persuasive on the ground that these two classes should have similar environmental correlations. Even here we cannot be sure to what extent the common DNA of twins shaped their development through internal processes, to what extent through the social reaction to their status of identical twinship. Adoptions then provide further material for study by separating the genetic heritage from the family environment. Good data are hard to find and may still be confounded by hidden biases of placement practices in the choice of adoptive homes.

Some of the heritage that is attributed to common DNA may instead depend on other shared experience, not only in the psychological realm but also in exposure to infections or to deficiencies of diet. Nevertheless, there is no good reason to question that half or more of the observed variability of intelligence within a white middle-class environment in Britain or the United States is attributable to genetic variation. This is a restricted circumstantial statement about a given population exposed to a given range

of environmental disparity. If suddenly all of the individuals in that population were to be pure-bred, so as to have a fixed genotype, then paradoxically we would say that the heritability was zero, for all of the observed variation would be attributable to the environment. Conversely, a standardization of environments would raise the heritability to 1.00. Likewise, redistributions of environmental variables, or the implementation of a new environmental parameter, could have a very large influence on the scores of a population regardless of the previously observed level of heritability of intelligence.

These conclusions are in fact not deeply disputed. It is the extrapolation of this reasoning to racial difference that has been appropriately criticized. For there is no rationale to support the use of figures of heritability observed within one group in predicting the genetic component of the differences observed between two races. Here we can expect to find differences both in genetic composition and in environmental experience, and indeed many interactions between them, to which present methods of analysis give no substantial point of attack. Until we know the critical environmental factors that do determine intellectual development among a variety of genotypes, no amount of matching of samples between two groups can convincingly nullify the environmental variable. It may be sufficient for the child to be told, or to be more subtly apprised, of a tradition of racial inferiority to drastically alter the outcome of innumerable acculturating encounters. These criticisms furnish no argument for or against racial (average) differences in genetic endowment; they suggest that the question is undecidable with present methods.[34]

[34] It is easy to see much social harm and difficult to foresee any social benefit from any systematic group labeling—individual variation still transcends the differences among groups. It may be part of a contemporary mania for ethnic identification which is succeeding the melting-pot ideals of a previous generation. These ethnic polemics are also in part a way of calling attention to the possible existence of genetic variables, which are systematically denied by some schools of social thought. Genetical theory is not, however, to be identified with racism since the differences between races are (1) the most complicated by autonomous value judgments and (2) the least accessible to reliable scientific methodology.

The distribution of I.Q. is too closely connected with opportunities for education and for employment to be dismissed as unimportant. Genetic investigations within well-defined racial and cultural groups may still give us important clues to the biological determination of mental development,[35] its specificities and its interaction with specific educational measures. This kind of skeptical but continued inquiry is diametrically opposed to the rote use of I.Q. tests for the aggregation of individuals who may have specific problems amenable to individualized treatment.

One of the gravest abuses of genetic knowledge is the fallacy of fatalism. This is the all-too-popular belief that a trait that has been genetically determined is unalterable for the lifetime of the individual. Most complex biological systems are subject to a wide range of genetic alterations, many of them having no direct effect but altering the vulnerability of the system to environmental influences. For example, an enzymatic defect, in alpha-antitrypsin, is associated with a high incidence of emphysema — but this lung disease rarely appears except in individuals who are heavy smokers or are exposed to other serious insults to their lung tissue.

Even when an important part of the cognitive system is, to the extent of present knowledge, irreversibly damaged as in some cases of congenital deafness, it is still possible to reduce the overall impact of the initial lesion. The congenitally deaf child who was given merely an equal opportunity in an ordinary school would probably emerge with an I.Q. effectively close to zero. But with proper training — learning to lip-read, for example — most of the secondary consequences of the defect can be mitigated. A priori it is almost certain that we have yet to discover highly individu-

[35] Much of the writing in the field of racial differences reflects a newly discovered insight into one branch of genetics—namely, populations—and obliviousness to another—namely, the developmental analysis of the way in which genes work. The hypothesis by which gene differences result in different neuronal configurations is hardly understood at all, but it is certainly so complex as to admit innumerable points of accessibility to environmental influences and paradoxes of specific interactions. There is certainly no gene for a large brain. There certainly are genes for regulating the timing of sensitivity of neuronal propagation in response to hormonal and other regulatory influences.

ated patterns of cognitive development, and that the educational system of the future must learn to be responsive to this individuality. Many educational failures today are the result of a mismatch between the phasing and sequential ordering of cognitive capabilities on the part of the child on the one hand and the demands of the curriculum on the other.[36] Far from inhumane stereotyping, further genetic analysis can give us the essential foundations for humane education addressed to the character of the individual child.

Even this discussion of specificity in education displays an unwonted emphasis on cognitive in contrast to emotional and motivational factors. The way in which a school operates as a social system — the interactions of the child with his peers, with his teacher, with his parents, and with the prevalent culture of childhood in relation to school — is likely to play as important a role in influencing the development of intellectual performance as any of the cognitive elements mentioned before. The converse must not be forgotten: the role of intellectual frustration in the emotionality of the child.

Phrases like "hereditary meritocracy" have helped to confuse the consequences of a deeper recognition of genetic factors in the development of intelligence and their humane application. The utopia pictured by Herrnstein[37] includes several fallacies. The expected alleviation of discriminatory differences in environmental opportunity may mitigate class injustice, but it will surely not eliminate major sources of environmental variation. Infections, traumatic accidents, nutritional retardation, emotional turmoil, will all continue to exact their toll. Even if there were but a single index of performance outcome, there are innumerable specific interactions among the input factors that make the concept of a unilinear ordering of genotypes a fantasy.

[36] These concerns are a possible reason for caution about integrated curricula which require uniform mastery of a variety of prerequisites to make any further progress at all.

[37] Richard J. Herrnstein, "I.Q.," *Atlantic Monthly,* CCXXVIII (September 1971), 43–64.

The idea of "hereditary" is also confused since, in popular usage, this ignores the reality of Mendelian segregation – namely, that two sons of the same parents may have quite disparate genotypes (although they tend to be correlated). Social inheritance, of course, tends to equalize the opportunities of members of a given family, subject to other traditional influences like the preference for the first born, sex roles, and other intrafamily interactions. Much of the widely felt sense of injustice about dynastic privilege is based precisely on the extent to which this is conferred irrespective of the genotype of the chosen. It is doubtful whether the strictest hereditary meritocracy, with its inevitable quota of lucky breaks, will be considered to be nearly as unjust as the existing system of favoritism by family and by class with its more limited accommodation to merit.[38]

Finally, Herrnstein's predictions about future developments include an implicit theory of political choice which may or may not be well founded. It is not at all clear that rational choice will predominate or, if it did, that it would allocate rewards in accordance with merit on any single scale. Allocations in terms of first order efficiency are bound to be modified by (1) humanitarian feelings, (2) the ambiguities of the merit of production compared to consumption, and (3) the concessions that any social contract in modern times must make to the power of the masses independently of their economic productivity. An alternative view is the expectation that economic rewards will be increasingly replaced by intangibles as the essential incentives for the meritocracy to continue to perform according to its ability. Even today status,

[38] The network of causal relationships that play upon educational and economic performance in the United States has been masterfully outlined by Otis D. Duncan, David L. Featherman, and Beverly Duncan, *Socioeconomic Background and Achievement* (New York: Seminar Press, 1972). One of their most telling points is the extent to which blackness per se is a handicap even after removing the factorial impact of intelligence, education, family background, and so on. Their measures even underestimate the total impact of racial discrimination via the secondary influence of blackness on those other variables. These authors carefully avoid speculations about the biological basis of the differences they analyzed, which is entirely appropriate since their data would offer little opportunity for rigorous inference, especially with respect to racial differences.

prestige, and certain forms of power comprise a growing part of the meaning of economic incentive as compared to material consumption.[39]

Eugenics and Genetic Engineering[40]

The idea of improving man, throughout the history of a divided earth, has subserved some particular ideology or national aspiration. Geneticists today have turned their attention to more realistic and humane opportunities for applying new biological knowledge — namely, the amelioration of serious disease. This approach responds to Popper's argument for piecemeal social engineering that it is far easier to establish a consensus about piecemeal evils than it is about global ideals. It may also be technically more feasible.

The popular view of contemporary medical genetics is colored by fantasies of genetic engineering — namely, the idea that our genes will soon be at the mercy of a master designer. In fact, we engineer genes today through the aggregate reproductive behavior that renews the species. Many technologies have long been available, and some of them tried, to alter that reproductive design. Decisions in this area are preeminently political rather than technological.[41] Concepts like cloning[42] and direct modification of the

[39] Heilbroner has pointed out that this is the real problem of income disparities. Unequal compensation in a free enterprise system is evidently a very small aggregate price to pay for the machinery of resource allocation. However, the concentration of economic gain, according to his argument, exerts its most insidious effects through its influence upon the political process, a view which appears to be substantiated by well-publicized contemporary inquiries. Robert L. Heilbroner, *The Limits of American Capitalism* (New York: Harper & Row, 1966).

[40] The phrase was introduced, as far as I know, by Bernhard J. Stern in a critique of eugenics by differential breeding: "Human Heredity and Environment," *Science and Society*, XIV (1950), 122–133 (reprinted in Bernhard J. Stern, *Historical Sociology: Selected Papers* [New York: Citadel Press, 1959]). The Lysenko controversy was then at its peak.

[41] It must, of course, be conceded that technical opportunity may induce policy temptations. It is difficult to see, however, how the application of any new technology could compete with Hitler's gas ovens. Energies devoted to decrying tech-

DNA, although demonstrated in simpler forms of life, face considerable practical obstacles before they can be realized in mammals and especially in man. After reading some of these well advertised prophecies, many an anxious parent has written to inquire what can be done for a particular genetically damaged child: the discrepancy between reality and expectation is a cruel one!

More intricate methods may ultimately be demonstrated as possible interventions in human development. They would then deserve and will surely face the most careful scrutiny with respect to the social utility of their further adoption. Ethical prohibitions against experiments that might have serious but unpredictable effects on the welfare of particular offspring are a serious practical limitation to the advance of these particular techniques. As portentous as these anticipated discoveries may be, we surely will have ample notice of their development, and many prior examples in experimental animals, before they can be widely available.

Until recently the only useful product of the medical geneticist was *advice* about future reproductive choices. After one damaged child was born, parents could be counseled about the risk of recurrence. They would then have the painful choice of taking further risks, at a level that might be statistically assessed, or of denying themselves additional children. The child no less than the parents bears the brunt of a handicap he can hardly be considered to deserve. During the last decade a combination of new biological technologies and a revolution in law and attitudes has opened a new path – namely, prenatal diagnosis and voluntary abortion.

---

nological progress may even be a diversion from building the kind of world society in which national and racial fanaticism can be contained. The technologies of mass communication and their remoteness from pluralistic control are far more pertinent than biology to the resurgence of totalitarian power. These complaints are, on the other hand, a justifiable warning about overweening optimism that technology can solve all human problems regardless of a moral social order.

[42] Joshua Lederberg, "Biological Innovation and Genetic Intervention," in John A. Behnke, ed., *Challenging Biological Problems: Directions Toward Their Solution* (New York: Oxford University Press, 1972).

For a number of genetic diseases it is now possible to obtain a diagnosis by sampling cells from the fetus at approximately twelve weeks of prenatal development. This can be done with a needle tap of the amniotic fluid, "amniocentesis." No significant hazard has been associated with this procedure in the hands of competent physicians. Cells from the amniotic fluid can be examined microscopically, or cultured in the laboratory and examined biochemically, for the presence of certain defects. Many genetic diseases can now be detected but they are all quite rare, so that less than one pregnancy in 100, among an average sample, would give operationally useful information. Ideally we should have means of therapy that could reverse the disease process for the fetuses so diagnosed; this is generally not feasible and the main recourse now is abortion. In fact, the availability of abortion poses a serious ethical problem for the exploration of more conservative therapeutic measures! These will be uncertain in the early stages and are therefore sure to result in a considerable residue of still damaged children, either from inefficient control of the disease or as a side effect of the treatment. For these reasons, prenatal diagnosis and abortion will probably preempt other approaches to genetic therapy.

The abortion issue itself aside, there are few moral ambiguities about the range of diseases to which this procedure of prenatal diagnosis ought to be applied if we could. From a practical standpoint the main problem is identifying the high-risk members of the population for whom the case yield is in worthwhile proportion to the costs and troubles of the procedure. Within restricted ethnic groups — for example, Tay Sachs disease among Ashkenazi Jews — it is easy to show[43] the cost effectiveness of a sequential prescreening procedure that can identify those 2.6 percent of parents who are at risk for prenatal monitoring of pregnancies. Steps to implement such a program have been initiated in Israel.

[43] J. S. O'Brien, "Tay-Sachs Disease: From Enzyme to Prevention," *Federation Proceedings,* Federation of American Societies for Experimental Biology, XXXII (1973), 191–199.

From a statistical standpoint the most urgent requirement for such a procedure today, in Africa and in the United States, would be sickle-cell disease. Unfortunately, it is not, at this writing, technically feasible to diagnose this disease during fetal life, although it is not difficult to detect the approximately one in ten members of the black population who are carriers of the sickle-cell gene. Screening programs for sickle-cell disease face the tragic dilemma of precisely what to do with the information about carriers at the present stage of biological knowledge.

Allegations that efforts to minimize this disease among blacks have a genocidal motive can hardly be justified on statistical grounds. In the United States only one black marriage in 100 is at risk of producing sickle-cell children, and the development of procedures for prenatal diagnosis of the homozygotes would allow even these parents to have their fair share of healthy children.

There are some diseases where the carrier state, as well as the disease state, can already be detected during fetal life. This opens up the technical possibility of abolishing a deleterious gene from the human population by systematic screening of carrier parents and by affording them the option of prenatal diagnosis and abortion of the 50 percent of their progeny who receive the gene. In these cases the detriment is not to the physical development of the child but rather the chance of further transmission to a future generation; the values of such a procedure are evidently quite limited. Given the very rapid rate of development of biomedical knowledge, future generations will be far more able to cope with these problems than we are ourselves. The prevention of disease among people should not be confused with a crusade against "bad genes."

Some geneticists are also concerned that there may be hidden advantages to genetic diversity, beyond the reproductive fitness that has already been discussed as an aspect of polymorphism. Since the net effect of these kinds of eugenical program would be primarily to shift the frequency of the adverse genes in question from a few percent to a few tenths of one percent, it is doubtful

that there are really any significant risks. The social utility problem is that of balancing the reduction in disease with the costs of the screening programs at the levels of the parents and the fetus.

Policy dilemmas are bound to arise around the issue of the freedom of choice of parents to continue with a pregnancy that they know to be at risk, or to refuse to acquire this information prior to the birth of the child. Our main problem today is, however, to make these procedures available to as many people as actively desire them; fortunately, while there are many perversities of human behavior, they may be sufficiently rare in this area that the direct and side-effect costs of enforcing against them may exceed the benefits. As long as we do not choose to look too closely at the *psychic* fitness of parents, these *genetic* issues will not add very much more to the burden of unfortunate children. In both kinds of situation, enlightenment should certainly be tried before compulsion.

At the present time most abortions stem from parental unwillingness to proceed with a healthy pregnancy rather than disease in the prospective child. Even if prenatal diagnosis were universally applied for every diagnosable disease, less than 5 percent of abortions in the United States would have a genetic indication. We can imagine, however, the development of embryological knowledge to the point where special or supernormal as well as subnormal capabilities might be predicted. According to this scenario, every pregnancy would be regarded as at risk and parents would exercise highly idiosyncratic choice with respect to the kind of children they would then produce. The psychosocial validity of this fantasy I leave to others. On the biological side, it should be stressed that (1) nothing remotely resembling such a technique is now avavilable even for early infancy much less fetal life, and (2) the knowledge of chemical measures to predict special intelligence will also open the door to environmental interventions.

A prototype of this problem already exists, however, with respect to sex. The chromosome pattern of the fetus is easily ascertained by prenatal cell sampling. Parental control of sex is

a theme of scientific prophecy that dates back at least to Condorcet, who may also have had the main key to its significance.[44] He foresaw that social progress toward equality of the sexes would override the potential bias of parental preference that might distort the sex ratio. The entire scenario is, in fact, a telling metaphor about the problem of sexual equality.

In certain families afflicted with sex-linked diseases like hemophilia, girls will be free of the disease whereas half the boys will be subject to lifetime suffering. There have been a few reports of aborting risky males on this indication, a procedure that may soon be refined with new methods of diagnosing the hemophilia gene itself during fetal life.

Even in the face of these examples there has been no observed stampede for parental control of the sex of their offspring; it is unlikely that any special legislative measures are required to control this technology. Visualize another scenario: the actual application of a legal system in which abortion for this cause was expressly forbidden and the police enforced it![45]

Convergence of Social and Genetic Research

Genetic medicine is rich with opportunities for social inquiry in arenas like patients' goals in seeking counseling, their compliance with therapeutic advice, the matching of values of patient and counselor, the side effects of disease at different levels of social organization — indeed, the same range of questions which would apply to other branches of medicine from primary care to transplant surgery. The special perceptions that people have about

[44] Frank E. Manuel, *The Prophets of Paris* (Cambridge: Harvard University Press, 1962), p. 99.

[45] The costs of enforcing social policy expressed as law have to be taken into account in the drafting of legislation in response to perceived social evils. One of the dangers of commissions on morality, as opposed to law, is that moral discussion may be all too encumbered by such practical side effects of pronouncements about what is absolutely good and evil.

their genes, contrasted to other aspects of their physical make-up, is reflected in the popular mythology of genetic fatalism — that what the genes have determined, man cannot undo.[46] It would be interesting to explore the sources of this mythology and its correlation with other widely held but mistaken beliefs.

One of the most pressing needs for a convergence of social and biological investigation is in the arena of demography. *Socioeconomic Background and Achievement* by Duncan, Featherman, and Duncan is an outstanding overview of the life cycle from the standpoint of education, occupation, and income. The word "health" does not appear in the index. Nor does "heredity," although this would be subject to serious methodological problems as already indicated. The fact that census data are traditionally collected with the household rather than the biological family as the primary unit of aggregation hinders the most elementary inquiries into evolutionary process.

Birth weight, adult weight, and stature are three variables perhaps more objectively ascertainable that are already known to interact with social inputs and outputs and could profitably be incorporated into further large-scale studies. Difficulties in linking mortality data with previous occupational experience of the decedents deprive us of important knowledge of occupational hazards to health, which in turn may be useful pointers to more pervasive environmental dangers. Conversely, many studies of environmental influence, ranging from cigarette smoking to education, would be improved if they were more often cognizant of sib-pair contrast designs, since siblings are likely to remove a considerable part of background variation both genetic and environmental. Such approaches would often be much sounder than the conven-

[46] For instance, the idea that cloning would be like making carbon copies of people as if monozygotic twins, even if reared in different times and places, had to share but a single soul. What would we say of the considerable number of individuals who are chimeras, twins within one body, carrying body cells derived from more than one egg? My experience as a teacher of genetics has been that the larger part of our task is to dispel folklore and misconceptions. Once this is done and a fresh start is possible, the rather particular point of view that underlies genetic analysis is then more than readily taught.

tional one of struggling to find individuals matched on a large number of irrelevant varibles.

Meta-Comments on the Nature of Man

Certain features are predictably associated with writings on vast themes. It would be several lifetimes work to review the existing literature: nothing in man's experience is totally irrelevant to his nature. Our writing thereon is therefore inevitably, at best, critical commentary rather than comprehensive review. Without a clear-cut map of man's present understanding of his own nature, no frontier of innovation is definable. Can there be accumulative value to this kind of production? It may be thought of as propaganda, with the aim of drawing attention to existing thoughts and facts rather than generating new ones. My introspection is intended to be analytical rather than pejorative: the present ensemble is a member of a rather large class of intellectual productions. The questions that naturally arise are: (1) According to what criteria does the existing allocation of intellectual effort as between innovation and reflection represent an optimum? and (2) What are the social processes that determine that allocation in the real world? The first question perhaps reflects the prejudices of the natural scientist; the second, the reflexes of the social philosopher.

That a production like this is described as a "paper" hints at the agonal ritual which is involved in committing a condensation of one's thoughts to a traditional medium of print. One's thoughts may change tomorrow but the paper will still be there. But without this traditional forum there may never be enough motivation for the effort of correlation, of superintending the emergence of a quasi-connected set of doctrines. Paper may soon be superseded by electronic communication, and by central files that, like the ideal data banks, can be corrected by their authors on the occasion of every perceived error. We may then indeed find that we have

to set computers talking to one another to try to discern the incremental content of successive productions and those most relevant to the caller's interest.

Eugenical thinking is supposed to be correlated with right-wing politics. However, biochemistry is supposed to be one of the more liberal sciences[47], and it may indeed be true that developmental genetics gives more encouragement for the hope of the perfectability of man in a reasonably short period of time than does the evolutionary perspective. I suppose I would have to admit some connection between my social origins, as the first generation progeny of a voluntary immigrant who saw America as a land of unlimited opportunity, and the perspective that individual qualities are paramount over racial stigmata. Developmental genetics provides scientific reinforcement for these archetypal ideas. Earlier in this century they were also iconoclastic, which is to say that they authenticated claims for recognition based on individual assertion rather than group tradition—in a word, personal social mobility.

Throughout this discussion we see the theme of social control of knowledge. This is, of course, one of the great mythopoetic dilemmas of human awareness, depicted in Genesis, in the Aeschylean Prometheus, in Berthold Brecht's interpretation of Galileo. Not every reader will share my conviction that the freedom to think, to innovate, is the central pillar of man's unique place in

[47] Mark H. Haller, *Eugenics: Hereditarian Attitudes in American Thought* (New Brunswick: Rutgers University Press, 1963); Donald K. Pickens, *Eugenics and the Progressives* (Nashville: Vanderbilt University Press, 1968); Ludmerer, *Genetics and American Society*. All these works acknowledge their debt to Richard Hofstadter's *Social Darwinism in American Thought* (Boston: Beacon Press, 1955). The variation in political outlook by scientific discipline — most recently studied by E. C. Ladd and S. M. Lipset, "Politics of Academic Natural Scientists and Engineers," *Science*, CLXXVI (1972), 1091–1100 — is a telling reminder of social influences on patterns of scientific thought. However, the mechanisms of this determination are by no means well demonstrated. The historical roots of genetics in agriculture (which rates as even more conservative than engineering) contrast with its later flourishing as a branch of biochemistry (whose political orientation begins to approach the avowed liberalism of the social sciences). Speculatively, this may be compared with the shift from populational to developmental genetic approaches to problems of human biology.

the universe. Even if this is rejected, there are so many practical obstacles to the control of innovation for purported human benefit that the repudiation of technology can hardly be viewed as a coherent program.[48] It is instead a complaint (too often justified) about the existing social organization, whose power may indeed be reinforced by the control of technological outputs. In the long run, new knowledge is the most revolutionary impulse of all.

The idea that society can be scientifically constructed has its own dangers, especially that complex systems may never be sufficiently understood for our finite models to be reliable. Anyone who has constructed complex computer programs knows how vulnerable they may be to the next unanticipated bit of information. The least that ought to be demanded of social-system design is a sensitivity analysis, to learn how rugged the system may be expected to be to unaccounted fluctuations. My skepticism about utopian applications of or complaints about science have already been expressed earlier in this article. Inevitable paradoxes arise from the different levels at which we apply our criteria of success. A system of nuclear stalemate that has been remarkably successful in avoiding global warfare for the past twenty-five years[49] also carries with it the hazard that mutually assured destruction will in fact eventuate: nor do we have any long-range alternative likely to traverse short-term catastrophe. Reduction

[48] Joshua Lederberg, "The Freedoms and the Control of Science: Notes from the Ivory Tower," *Southern California Law Review*, XLV (1972), 596–614.

[49] The engagement of scientists in complex policy struggles, like those of strategic defense, places them in perplexing trials of conscience and of utility. The discipline of rigorous, quantitative thinking, and general knowledge of the underlying technology of weapons systems, can be valuable by-products of professional work in civilian science. However, policy judgments can never have the authenticity of scientific ones which are hammered out in public dialogue and tested by reproducible experiments. Deeply felt convictions about policy may lead scientists to invoke the unwarranted authority of science in ways that dull the precision of scientific reasoning and dampen its credibility. For an egregious example that expresses incontestable *sentiments*, note C. P. Snow's remarks: "Within at the most ten years some of those bombs are going off . . . that is a certainty. Between a risk and a certainty a sane man does not hesitate. It is the plain duty of scientists to explain this either–or. It is a duty which seems to me to come from the moral nature of the scientific activity itself" (*Science*, CXXXIII [1961], 259).

of arms may even increase the instability of the world system, although by every other account it would have to be regarded as "a good thing." Deep-seated convictions about the immorality of warfare, when they were expressed in the pacifist movements of the 1930s, gave Hitler almost all that he needed by way of advantage for world conquest. That standard may be totally irrelevant to the world situation today.

All in all, the biological student of man must respect the complexity of the systems that have emerged with the tools that the evolution of the brain has brought into being. But if he then devotes all his energies to those problems which are merely tractable by scientific analysis, he may by definition divert the opportunity to contribute to the betterment of human nature.